

WHAT IS CLAIMED IS:

- 1 1. A drive circuit which produces a drive signal for a device having a
2 piezoelectric actuator, wherein the drive circuit is arranged to change dynamically the
3 drive signal during real time operation of the device.
- 1 2. The apparatus of claim 1, wherein the drive circuit changes dynamically a
2 shape of a waveform of the drive signal.
- 1 3. The apparatus of claim 1, wherein the drive signal comprises charge packets
2 which are integrated by the piezoelectric actuator.
- 1 4. The apparatus of claim 1, wherein the drive circuit comprises a pulse width
2 modulator which changes dynamically, during real time operation of the device, widths
3 of pulses from which the drive signal is derived.
- 1 5. The apparatus of claim 1, wherein the drive circuit changes dynamically the
2 drive signal in dependence upon an operational parameter of the device.
- 1 6. The apparatus of claim 1, wherein the drive circuit changes dynamically the
2 drive signal in dependence upon a sensed operational parameter of the device.
- 1 7. The apparatus of claim 6, wherein the sensed operational parameter of the
2 device is resonance of the piezoelectric actuator.
- 1 8. The apparatus of claim 6, wherein the sensed operational parameter of the
2 device is temperature.
- 1 9. The apparatus of claim 1, wherein the drive circuit changes dynamically the
2 drive signal in dependence upon a sensor signal which is obtained from a sensor.
- 1 10. The apparatus of claim 9, wherein the sensor signal bears an indication of
2 resonance of the piezoelectric actuator.

1 11. The apparatus of claim 9, wherein the sensor signal bears an indication of
2 temperature.

1 12. The apparatus of claim 1, wherein the drive circuit changes dynamically one
2 of voltage and frequency of the drive signal.

1 13. The apparatus of claim 1, wherein the drive circuit changes dynamically one
2 of voltage and frequency of the drive signal in accordance with an input signal to the
3 drive circuit.

1 14. The apparatus of claim 13, wherein the input signal is obtained from a user
2 input device.

1 15. The apparatus of claim 1, wherein the device is a pump.

1 16. The apparatus of claim 15, wherein the drive circuit changes dynamically
2 the drive signal whereby the drive signal varies over time so that an essentially non-
3 continuous dosage of fluid is delivered by the pump.

1 17. The apparatus of claim 16, wherein the drive circuit changes dynamically
2 the drive signal whereby the drive signal varies over time so that an essentially non-
3 continuous intermittent dosage of fluid is delivered by the pump.

1 18. A drive circuit which produces a digital drive signal for a device having a
2 piezoelectric actuator, wherein the drive circuit is arranged to generate the drive signal
3 in accordance with an analog input signal to the drive circuit.

1 19. The apparatus of claim 18, wherein the drive circuit is arranged to change
2 dynamically the drive signal in accordance with the analog input signal to the drive
3 circuit.

1 20. The apparatus of claim 18, wherein the analog input signal to the drive
2 circuit is acquired from a sensor.

1 21. The apparatus of claim 20, wherein the analog input signal bears an
2 indication of resonance of the piezoelectric actuator.

1 22. The apparatus of claim 20, wherein the analog input signal bears an
2 indication of temperature.

1 23. The apparatus of claim 18, wherein the analog input signal bears an
2 indication of one of a desired voltage and a desired frequency of the drive signal.

1 24. The apparatus of claim 23, wherein the input signal is obtained from a user
2 input device.

1 25. A drive circuit which produces a drive signal for a device having a
2 piezoelectric actuator, wherein the drive circuit is arranged to generate the drive signal
3 whereby a waveform of the drive signal is shaped in dependence upon an operational
4 parameter of the device.

1 26. The apparatus of claim 25, wherein the drive circuit dynamically shapes the
2 waveform of the drive signal in dependence upon the operational parameter of the
3 device during real time operation of the device.

1 27. The apparatus of claim 25, wherein the drive signal comprises charge
2 packets which are integrated by the piezoelectric actuator.

1 28. The apparatus of claim 25, wherein the drive circuit comprises a pulse width
2 modulator which shapes widths of pulses from which the waveform of the drive signal
3 is derived in dependence upon the operational parameter of the device.

1 29. The apparatus of claim 25, wherein the drive circuit shapes the waveform of
2 the drive signal in dependence upon a sensed operational parameter of the device.

1 30. The apparatus of claim 29, wherein the sensed operational parameter of the
2 device is resonance of the piezoelectric actuator.

1 31. The apparatus of claim 29, wherein the sensed operational parameter of the
2 device is temperature.

1 32. A drive circuit which produces a drive signal for a device having a
2 piezoelectric actuator, wherein the drive circuit is arranged to generate the drive signal
3 whereby a waveform of the drive signal is shaped in dependence upon a sensor signal
4 which is obtained from a sensor.

1 33. The apparatus of claim 32, wherein the drive circuit dynamically shapes the
2 waveform of the drive signal in dependence upon the operational parameter of the
3 device during real time operation of the device.

1 34. The apparatus of claim 32, wherein the drive signal comprises charge
2 packets which are integrated by the piezoelectric actuator.

1 35. The apparatus of claim 32, wherein the drive circuit comprises a pulse width
2 modulator which shapes widths of pulses from which the waveform of the drive signal
3 is derived in dependence upon the sensor signal which is obtained from the sensor.

1 36. The apparatus of claim 32, wherein the sensor signal bears an indication of
2 resonance of the piezoelectric actuator.

1 37. The apparatus of claim 32, wherein the sensor signal bears an indication of
2 temperature.

1 38. The apparatus of claim 32, wherein the sensor signal bears an indication of
2 voltage.

1 39. The apparatus of claim 32, wherein the drive circuit changes voltage of the
2 drive signal in accordance with the input to the drive circuit.

1 40. A drive circuit which produces a drive signal for a device having a
2 piezoelectric actuator, wherein the drive circuit is arranged to generate the drive signal
3 whereby one of voltage and frequency of the drive signal is determined in dependence
4 upon an input signal to the drive circuit.

1 41. The apparatus of claim 40, wherein the input signal is obtained from a user
2 input device.

1 42. The apparatus of claim 40, wherein the drive circuit dynamically changes
2 the one of voltage and frequency of the drive signal during real time operation of the
3 device.

1 43. The apparatus of claim 40, wherein the drive signal comprises charge
2 packets which are integrated by the piezoelectric actuator.

1 44. A drive circuit which produces a drive signal for a pump having a
2 piezoelectric actuator, wherein the drive circuit is arranged to generate the drive signal
3 whereby the drive signal varies over time so that an essentially non-continuous dosage
4 of fluid is delivered by the pump.

1 45. The apparatus of claim 44, wherein the drive circuit dynamically changes
2 the drive signal over time during real time operation of the pump whereby a differing
3 dosage of fluid is delivered by the pump after the change.

1 46. The apparatus of claim 44, wherein the drive signal is a digital signal.

1 47. The apparatus of claim 44, wherein the drive circuit comprises a pulse width
2 modulator which shapes widths of pulses from which the waveform of the drive signal
3 is derived so that the drive signal varies over time.

1 48. A piezoelectric-actuated device comprising:
2 a piezoelectric actuator which is responsive to a drive signal; and
3 a drive circuit which produces the drive signal, the drive circuit being arranged
4 to change dynamically the drive signal during real time operation of the device.

1 49. The apparatus of claim 48, wherein the device is a pump having a pump
2 body for at least partially defining a pumping chamber and an inlet and an outlet which
3 communicate with the pumping chamber, wherein the piezoelectric actuator is situated
4 in the pump body and responsive to the drive signal for pumping fluid between the inlet
5 and outlet; and wherein the drive circuit produces the drive signal, the drive circuit

6 being arranged to change dynamically the drive signal during real time operation of the
7 pump.

1 50. The apparatus of claim 49, wherein the drive circuit changes dynamically
2 the drive signal whereby the drive signal varies over time so that an essentially non-
3 continuous dosage of fluid is delivered by the pump.

1 51. The apparatus of claim 50, wherein the drive circuit changes dynamically
2 the drive signal whereby the drive signal varies over time so that an essentially non-
3 continuous intermittent dosage of fluid is delivered by the pump.

1 52. The apparatus of claim 48, wherein the drive circuit changes dynamically a
2 shape of a waveform of the drive signal.

1 53. The apparatus of claim 48, wherein the drive signal comprises charge
2 packets which are integrated by the piezoelectric actuator.

1 54. The apparatus of claim 48, wherein the drive circuit comprises a pulse width
2 modulator which changes dynamically, during real time operation of the device, widths
3 of pulses from which the drive signal is derived.

1 55. The apparatus of claim 48, wherein the drive circuit changes dynamically
2 the drive signal in dependence upon an operational parameter of the device.

1 56. The apparatus of claim 48, wherein the drive circuit changes dynamically
2 the drive signal in dependence upon a sensed operational parameter of the device.

1 57. The apparatus of claim 56, wherein the sensed operational parameter of the
2 device is resonance of the piezoelectric actuator.

1 58. The apparatus of claim 56, wherein the sensed operational parameter of the
2 device is temperature.

1 59. The apparatus of claim 48, wherein the drive circuit changes dynamically
2 the drive signal in dependence upon a sensor signal which is obtained from a sensor.

1 60. The apparatus of claim 59, wherein the sensor signal bears an indication of
2 resonance of the piezoelectric actuator.

1 61. The apparatus of claim 59, wherein the sensor signal bears an indication of
2 temperature.

1 62. The apparatus of claim 48, wherein the drive circuit changes dynamically
2 one of voltage and frequency of the drive signal.

1 63. The apparatus of claim 48, wherein the drive circuit changes dynamically
2 one of voltage and frequency of the drive signal in accordance with an input signal to
3 the drive circuit.

1 64. The apparatus of claim 63, wherein the input signal is obtained from a user
2 input device.

1 65. A piezoelectric-actuated device comprising:
2 a piezoelectric which is responsive to a digital drive signal; and
3 a drive circuit which produces the drive signal, the drive circuit being arranged
4 to generate the drive signal in accordance with an analog input signal to the drive
5 circuit.

1 66. The apparatus of claim 65, wherein the device is a pump comprising a pump
2 body for at least partially defining a pumping chamber and an inlet and an outlet which
3 communicate with the pumping chamber, and wherein the piezoelectric actuator is
4 situated in the pump body and responsive to the digital drive signal for pumping fluid
5 between the inlet and outlet.

1 67. The apparatus of claim 65, wherein the drive circuit is arranged to change
2 dynamically the drive signal in accordance with the analog input signal to the drive
3 circuit.

1 68. 59The apparatus of claim 65, wherein the analog input signal to the drive
2 circuit is acquired from a sensor.

1 69. The apparatus of claim 59, wherein the analog input signal bears an
2 indication of resonance of the piezoelectric actuator.

1 70. The apparatus of claim 59, wherein the analog input signal bears an
2 indication of temperature.

1 71. The apparatus of claim 65, wherein the analog input signal bears an
2 indication of one of a desired voltage and a desired frequency of the drive signal.

1 72. The apparatus of claim 71, wherein the input signal is obtained from a user
2 input device.

1 73. A piezoelectric-actuated device comprising:
2 a piezoelectric actuator which is responsive to a drive signal; and
3 a drive circuit which produces the drive signal, the drive circuit being arranged
4 to generate the drive signal in dependence upon an operational parameter of the device.

1 74. The apparatus of claim 73, wherein the device is a pump having a pump
2 body for at least partially defining a pumping chamber and an inlet and an outlet which
3 communicate with the pumping chamber, wherein the piezoelectric actuator is situated
4 in the pump body and responsive to the drive signal for pumping fluid between the inlet
5 and outlet.
6

1 75. The apparatus of claim 73, wherein the drive circuit dynamically shapes the
2 waveform of the drive signal in dependence upon the operational parameter of the
3 pump during real time operation of the device.

1 76. The apparatus of claim 73, wherein the drive signal comprises charge
2 packets which are integrated by the piezoelectric actuator.

1 77. The apparatus of claim 73, wherein the drive circuit comprises a pulse width
2 modulator which shapes widths of pulses of the waveform of the drive signal in
3 dependence upon the operational parameter of the device.

1 78. The apparatus of claim 73, wherein the drive circuit shapes the waveform of
2 the drive signal in dependence upon a sensed operational parameter of the device.

1 79. The apparatus of claim 78, wherein the sensed operational parameter of the
2 pump is resonance of the piezoelectric actuator.

1 80. The apparatus of claim 78, wherein the sensed operational parameter of the
2 device is temperature.

1 81. A piezoelectric-actuated device comprising:
2 a piezoelectric actuator which is responsive to a drive signal;
3 a sensor which generates a sensor signal; and
4 a drive circuit which produces the drive signal, the drive circuit being arranged
5 to generate the drive signal in dependence upon the sensor signal.

1 82. The apparatus of claim 81, wherein the device is a pump comprising a pump
2 body for at least partially defining a pumping chamber and an inlet and an outlet which
3 communicate with the pumping chamber, wherein the piezoelectric actuator is situated
4 in the pump body and responsive to the drive signal for pumping fluid between the inlet
5 and outlet.

1 83. The apparatus of claim 81, wherein the drive circuit dynamically shapes the
2 waveform of the drive signal in dependence upon the operational parameter of the
3 pump during real time operation of the device.

1 84. The apparatus of claim 81, wherein the drive signal comprises charge
2 packets which are integrated by the piezoelectric actuator.

1 85. The apparatus of claim 81, wherein the drive circuit comprises a pulse width
2 modulator which shapes widths of pulses of the waveform of the drive signal in
3 dependence upon the sensor signal.

1 86. The apparatus of claim 81, wherein the sensor signal bears an indication of
2 resonance of the piezoelectric actuator.

1 87. The apparatus of claim 81, wherein the sensor signal bears an indication of
2 temperature.

1 88. The apparatus of claim 81, wherein the sensor signal bears an indication of
2 voltage.

1 89. The apparatus of claim 81, wherein the drive circuit changes voltage of the
2 drive signal in accordance with the input to the drive circuit.

1 90. A piezoelectric-actuated device comprising:
2 a piezoelectric actuator which is responsive to a drive signal; and
3 a drive circuit which produces the drive signal, the drive circuit being arranged
4 to generate the drive signal whereby one of voltage and frequency of the drive signal is
5 determined in dependence upon an input signal to the drive circuit.

1 91. The apparatus of claim 63, wherein the device is a pump comprising a pump
2 body for at least partially defining a pumping chamber and an inlet and an outlet which
3 communicate with the pumping chamber, and wherein the piezoelectric actuator is
4 situated in the pump body and responsive to the drive signal for pumping fluid between
5 the inlet and outlet.

1 92. The apparatus of claim 63, wherein the input signal is obtained from a user
2 input device.

1 93. The apparatus of claim 63, wherein the drive circuit dynamically changes
2 the one of voltage and frequency of the drive signal during real time operation of the
3 device.

1 94. The apparatus of claim 63, wherein the drive signal comprises charge
2 packets which are integrated by the piezoelectric actuator.

1 95. A piezoelectric-actuated device comprising:
2 a piezoelectric actuator which is responsive to a drive signal; and

3 a drive circuit which produces the drive signal, the drive circuit being arranged
4 to generate the drive signal whereby the drive signal varies over time so that the device
5 is operated essentially non-continuously.

1 96. The apparatus of claim 95, wherein the device is a pump comprising a pump
2 body for at least partially defining a pumping chamber and an inlet and an outlet which
3 communicate with the pumping chamber, and wherein the piezoelectric actuator is
4 situated in the pump body and responsive to the drive signal for pumping fluid between
5 the inlet and outlet; and wherein the drive signal varies over time so that an essentially
6 non-continuous dosage of fluid is delivered by the pump.

1 97. The apparatus of claim 96, wherein the drive circuit dynamically changes
2 the drive signal over time during real time operation of the pump whereby a differing
3 dosage of fluid is delivered by the pump after the change.

1 98. The apparatus of claim 95, wherein the drive signal comprises charge
2 packets which are integrated by the piezoelectric actuator.

1 99. The apparatus of claim 95, wherein the drive circuit comprises a pulse width
2 modulator which shapes widths of pulses of the waveform of the drive signal so that the
3 drive signal varies over time.

1 100. A method of operating a device having a piezoelectric actuator which is
2 responsive to a drive signal, the method comprising:
3 dynamically changing the drive signal during real time operation of the device;
4 actuating the piezoelectric actuator in response to the drive signal.

1 101. The method of claim 100, further comprising dynamically changing the
2 drive signal whereby the drive signal varies over time so that the device operates on an
3 essentially non-continuous basis.

1 102. The method of claim 100, wherein the device is a pump and the
2 piezoelectric actuator is situated in a pump body and responsive to the drive signal for
3 pumping fluid between an inlet and an outlet of the pump body, and wherein the
4 method further comprises:

5 dynamically changing the drive signal during real time operation of the pump;
6 actuating the piezoelectric actuator in response to the drive signal to pump the
7 fluid between the inlet and the out of the pump body.

1 103. The method of claim 102, further comprising dynamically changing the
2 drive signal whereby the drive signal varies over time so that an essentially non-
3 continuous dosage of fluid is delivered by the pump.

1 104. The method of claim 103, further comprising dynamically changing the
2 drive signal whereby the drive signal varies over time so that an essentially non-
3 continuous intermittent dosage of fluid is delivered by the pump.

1 105. The method of claim 100, wherein the method comprises dynamically
2 changing a shape of a waveform of the drive signal.

1 106. The method of claim 100, wherein the drive signal comprises charge
2 packets which are integrated by the piezoelectric actuator.

1 107. The method of claim 100, further comprising using a pulse width
2 modulator for dynamically changing, during real time operation of the pump, widths of
3 pulses from which the drive signal is derived.

1 108. The method of claim 100, further comprising dynamically changing the
2 drive signal in dependence upon an operational parameter of the device.

1 109. The method of claim 100, further comprising dynamically changing the
2 drive signal in dependence upon a sensed operational parameter of the device.

1 110. The method of claim 109, wherein the sensed operational parameter of the
2 pump is resonance of the piezoelectric actuator.

1 111. The method of claim 109, wherein the sensed operational parameter is
2 temperature.

1 112. The method of claim 100, further comprising dynamically changing the
2 drive signal in dependence upon a sensor signal which is obtained from a sensor.

1 113. The method of claim 112, wherein the sensor signal bears an indication of
2 resonance of the piezoelectric actuator.

1 114. The method of claim 112, wherein the sensor signal bears an indication of
2 temperature.

1 115. The method of claim 100, further comprising dynamically changing one of
2 voltage and frequency of the drive signal.

1 116. The method of claim 100, further comprising dynamically changing one of
2 voltage and frequency of the drive signal in accordance with an input signal to the drive
3 circuit.

1 117. The method of claim 116, further comprising obtaining the input signal
2 from a user input device.

1 118. A method of operating a device having a piezoelectric actuator which is
2 responsive to a drive signal , the method comprising:
3 generating the drive signal in accordance with an analog input signal to the drive
4 circuit;
5 actuating the piezoelectric actuator in response to the drive signal.

1 119. The method of claim 118, wherein the device is a piezoelectric pump
2 having the piezoelectric actuator situated in a pump body and responsive to the drive
3 signal for pumping fluid between an inlet and an outlet of the pump body, and wherein
4 the method further comprises actuating the piezoelectric actuator in response to the
5 drive signal to pump the fluid between the inlet and the outlet of the pump body.

1 120. The method of claim 118, further comprising dynamically changing the
2 drive signal in accordance with the analog input signal to the drive circuit.

1 121. The method of claim 118, further comprising acquiring the analog input
2 signal to the drive circuit from a sensor.

1 122. The method of claim 121, wherein the analog input signal bears an
2 indication of resonance of the piezoelectric actuator.

1 123. The method of claim 121, wherein the analog input signal bears an
2 indication of temperature.

1 124. The method of claim 118, wherein the analog input signal bears an
2 indication of one of a desired voltage and a desired frequency of the drive signal.

1 125. The method of claim 124, further comprising obtaining the input signal
2 from a user input device.

1 126. A method of operating a device having a piezoelectric actuator which is
2 responsive to a drive signal , the method comprising:
3 generating the drive signal in dependence upon an operational parameter of the
4 device;
5 actuating the piezoelectric actuator in response to the drive signal.

1 127. The method of claim 126, wherein the device is a piezoelectric pump
2 having the piezoelectric actuator situated in a pump body and responsive to the drive
3 signal for pumping fluid between an inlet and an outlet of the pump body, and wherein
4 the method further comprises actuating the piezoelectric actuator in response to the
5 drive signal to pump the fluid between the inlet and the outlet of the pump body.

1 128. The method of claim 126, further comprising dynamically shaping the
2 waveform of the drive signal in dependence upon the operational parameter of the
3 device during real time operation of the device.

1 129. The method of claim 126, wherein the drive signal comprises charge
2 packets which are integrated by the piezoelectric actuator.

1 130. The method of claim 126, further comprising using a pulse width
2 modulator to shape widths of pulses of the waveform of the drive signal in dependence
3 upon the operational parameter of the device.

1 131. The method of claim 126, further comprising the drive circuit shaping the
2 waveform of the drive signal in dependence upon a sensed operational parameter of the
3 device.

1 132. The method of claim 131, wherein the sensed operational parameter of the
2 device is resonance of the piezoelectric actuator.

1 133. The method of claim 131, wherein the sensed operational parameter is
2 temperature.

1 134. A method of operating a device having a piezoelectric actuator which is
2 responsive to a drive signal , the method comprising:
3 generating the drive signal in dependence upon a sensor signal;
4 actuating the piezoelectric actuator in response to the drive signal.

1 135. The method of claim 134, wherein the device is a piezoelectric pump
2 having the piezoelectric actuator situated in a pump body and responsive to the drive
3 signal for pumping fluid between an inlet and an outlet of the pump body, and wherein
4 the method further comprises actuating the piezoelectric actuator in response to the
5 drive signal to pump the fluid between the inlet and the outlet of the pump body.

1 136. The method of claim 134, further comprising dynamically shaping the
2 waveform of the drive signal in dependence upon a sensor signal during real time
3 operation of the device.

1 137. The method of claim 134, wherein the drive signal comprises charge
2 packets which are integrated by the piezoelectric actuator.

1 138. The method of claim 134, further comprising using a pulse width
2 modulator for shaping widths of pulses from which the waveform of the drive signal is
3 derived in dependence upon the sensor signal.

1 139. The method of claim 134, wherein the sensor signal bears an indication of
2 resonance of the piezoelectric actuator.

1 140. The method of claim 134, wherein the sensor signal bears an indication of
2 temperature.

1 141. The method of claim 134, wherein the sensor signal bears an indication of
2 voltage.

1 142. The method of claim 134, further comprising the drive circuit changing
2 voltage of the drive signal in accordance with the input to the drive circuit.

1 143. A method of operating a device having a piezoelectric actuator which is
2 responsive to a drive signal, the method comprising:
3 generating the drive signal whereby one of voltage and frequency of the drive
4 signal is determined in dependence upon an input signal to the drive circuit;
5 actuating the piezoelectric actuator in response to the drive signal

1 144. The method of claim 143, wherein the device is a piezoelectric pump
2 having the piezoelectric actuator situated in a pump body and responsive to the drive
3 signal for pumping fluid between an inlet and an outlet of the pump body, and wherein
4 the method further comprises actuating the piezoelectric actuator in response to the
5 drive signal to pump the fluid between the inlet and the outlet of the pump body.

1 145. The method of claim 143, further comprising obtaining the input signal
2 from a user input device.

1 146. The method of claim 143, further comprising dynamically changing the
2 one of voltage and frequency of the drive signal during real time operation of the
3 device.

1 147. The method of claim 143, wherein the drive signal comprises charge
2 packets which are integrated by the piezoelectric actuator.

1 148. A method of operating a device having a piezoelectric actuator which is
2 responsive to a drive signal, the method comprising varying the drive signal varies over
3 time so that the device operates essentially non-continuously.

1 149. The method of claim 148, wherein the device is a piezoelectric pump
2 having the piezoelectric actuator situated in a pump body and responsive to the drive
3 signal for pumping fluid between an inlet and an outlet of the pump body, and wherein
4 the method further comprises varying the drive signal varies over time so that an
5 essentially non-continuous dosage of fluid is delivered by the pump.

1 150. The method of claim 149, further comprising dynamically changing the
2 drive signal over time during real time operation of the pump whereby a differing
3 dosage of fluid is delivered by the pump after the change.

1 151. The method of claim 148, wherein the drive signal comprises charge
2 packets which are integrated by the piezoelectric actuator.

1 152. The method of claim 148, further comprising using a pulse width
2 modulator for shaping widths of pulses of the waveform of the drive signal so that the
3 drive signal varies over time.